diseases"); and Metcalf and Collins's "Present Status of the Chestnut Bark Disease" (due to *Diaporthe parasitica,* which thus far has baffled all attempts at control, by anything less than the destruction of the diseased trees).

In Dr. Clinton's "Report of the Station Botanist" (Conn. Agricul. Expt. Station, 1908) he takes a more hopeful view of the future of the chestnut bark disease, believing that the trouble is largely due to "winter injury" rather than to the fungus above named, and that it "is now probably about at the height of its development, so that not much additional harm may be expected." Another paper in the same report takes up another puzzling disease, peach yellows—and here, also, a suggestion is made as to its nature which at least has the merit of some probability. The closing paper gives the results of artificial cultures of *Phytophthora* of different species. This will be most useful to mycologists who may wish to introduce this method of study in their laboratories.

Other papers which may be mentioned here are Professor DeLoach's "Studies on the *Colletotrichum gossypii*" (Bull. 85, Georgia Expt. Station); W. T. Horne's "Report of the Department of Vegetable Pathology" in the report of the Estacion Central Agronomica of Cuba (1905–09), and an earlier one by the same author devoted to coconut diseases (Bull. 15); Freeman and Johnson's "Loose Smuts of Barley and Wheat" (Bull. 152, Bureau of Plant Industry); C. W. Edgerton's "Perfect Stage of the Cotton Anthracnose" (*Mycologia,* May, 1909); the same author's "Anthracnose or Pod Spot of Beans" (Bull. 116, La. Expt. Sta.); J. G. Grossenbacher's "Mycosphaerella Wilt of Melons" (Tech. Bull. 9, N. Y. Expt. Sta.); and G. W. Wilson's "Notes on Peronosporales for 1907" (Bull. Upper Iowa University, XI., 3).

We have space for only brief mention of the following, also: Century XXIX. of "Fungi Columbiani" (Elam Bartholomew, Stockton, Kans.) devoted wholly to fungi collected in Arkansas; Fawcett's "Fungi Parasitic upon Aleyrodes citri" (Special Studies, 1; Univ. Florida), with six plates; Rorer's "Bacterial Disease of the Peach" (*Mycologia,* January, 1909); Edwards and Barlow's "Legume Bacteria" (Bull. 169, Ontario Agricul. Coll.).

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SPECIAL ARTICLES

THE CONSERVATION OF MASS AND THE PASSING OF MATTER

TO THE EDITOR OF SCIENCE: The article by Professor Lewis in the *Technology Quarterly,* discussed in your issue of April 23, 1909, by Professor Speyers, is one answer to the obvious necessity for an enlargement and restatement of some of the fundamental concepts of physics.

The discovery of radioactivity by M. Henri Becquerel, and that of polonium by Mme. Curie, initiating us into the knowledge of a new order of phenomena, together with the observation by P. Curie and Laborde of a continual production of heat by radium, and the splendid experiment of Kaufmann on the variation of mass with velocity, finally the suggestion by Rutherford and Soddy that the atoms of the radio-elements disintegrate with production of helium, confirmed in the face of great difficulties by Sir William Ramsay and Mr. Soddy, have placed before us an array of new facts for which new doctrines are imperatively needed.

We may recall that the investigations of Larmor, J. J. Thomson, Hicks and others, exhibit to us a conception of an atom as a world in miniature, where internal revolutions and reactions of distinct internal entities at enormous speeds give a basis for the discussion of latent energies implied by the physical fact of the inertia of the atom.

That the mass of a body is nothing but the energy of its ethereal rotation is a view which I have held tentatively. Following the equations used by Professor Lewis, and introducing this further premise, let $M =$ momentum, $M' = Mr =$ angular momentum, or "moment of momentum," of the ether, where r is the radius of gyration of the reciprocating rotations of the ether. The complex of these integrated rotations constitutes an electromagnetic wave whose amplitude diminishes with r as the spherical wave-front expands. Let

P = normal radiation-pressure corresponding to the radiant energy per unit of volume of the ether = ethereal moment of momentum transferred per unit of time to a normal surface; m = the mass of a body, an atom for example, E, its energy, either actual or potential, v, its velocity; V = velocity of light; and t = time. Then according to the Maxwell-Bartoli formula,

$$P = \frac{(1+\rho)}{V} \times \frac{dE}{dt}$$

where ρ is the reflecting power of the surface which receives the radiation. Under the action of this radiant pressure, there is a transference of energy from the ether to matter which may be regarded as the transferring of a definite amount of angular momentum from the ether to matter, according to the equation

$$M'/t = dE = dm \times V^2. \qquad (1)$$

Whether the energy received by an absorbent particle from radiation shall be manifested in the body as kinetic energy of mechanical motion, or as thermal energy, is a detail depending on whether the particle is free to move, or is constrained by its linkage to other particles.

We may distinguish between the free ether and the ether which is bound in material vortical motion; but in a slightly different sense the ether can never be said to be free, for it is everywhere in contact with itself. The angular momentum of a free material body is invariable. It can not be altered from within, and can only be transferred by contact. But the angular momentum of the ether which is everywhere in contact is always transferred. Mass, as a property of ether, is purely temporary. The ethereal mass is strictly proportional to the radiant energy and disappears with it. Equation (1) which expresses a relation between ether and matter, may, however, be applied to the ether alone, if m and E denote its transient mass and energy during radiant activity.

The earth, by virtue of its orbital motion, possesses a great store of potential energy for the production of heat. An atom, by virtue of the internal motions of its electrons, possesses a relatively enormous potential energy. Neither of these stores of energy can be converted into heat except by some sort of collision which disturbs and disarranges the harmonious motion. The distinction between actual and potential energy depends upon the point of view. The kinetic energy of terrestrial orbital motion is actual mechanical energy, but in relation to thermal energy the kinetic energy is potential. Upon this energy of a planet's orbital revolution there are superimposed the kinetic energy of its axial rotation, that of the motion of the entire solar system along the sun's way, relatively to the gravitational center of motion in the galactic agglomeration of which our sun forms a part, and the unknown motion of the galaxy as a whole, relatively to some point in absolute space. The total energy of a body is an unknown quantity, save as it becomes theoretically possible to predict it in the way that Professor Lewis has pointed out.

Recognizing that only a small part of the total energy-content of a body comes within our cognizance, and that comparatively only a brief interval in its history can come under observation, I think that we may, with all humility in acknowledgment of our limitations, nevertheless find in the relations between light and matter an epitome of the history of the physical universe. If mass can be transferred through light, it follows that mass may be said to *originate* from light, that is, from ethereal rotation so circumstanced that the motion becomes circumscribed and the energy prevented from dissipation by ordinary agencies.

The mechanical action of light observed by Crookes, although not certainly separated by him from mechanical action due to the residual gas of his vacuum tubes, has now been completely demonstrated by Lebedew, and by Nichols and Hull, and has been shown by the latter to be independent of the wave-length, and in agreement with the prediction from electromagnetic theory.

Although the rapid motion of finely divided matter in comets' tails may be explained on the hypothesis of electric repulsion, the demand for a large solar electric field has been

considered a difficulty, and astronomers have welcomed the suggestion that this motion and that of similar material in the solar corona may be due to light-pressure. The acceleration produced by solar gravity at the earth's distance being

$$\frac{0.593}{982.15} = \frac{1}{1656}$$

of the acceleration by terrestrial gravity at the surface of a spherical earth, the light-pressure from solar radiation at this distance on a body of small size whose receiving surface is very large compared with its volume and mass, may exert an accelerative action several times that due to solar gravity, the differential acceleration giving an accumulating velocity away from the sun.

Professor Edwin B. Frost and Mr. J. A. Parkhurst find from their spectroscopic observations of Comet Morehouse that "particles of the same [chemical] constitution are thrown out from the head at angles at least 40° asunder."[1] Bredichin's hypothesis in explanation of cometary tails of various types requires in this case that the particles forming individual component streamers of the tail shall be of different sizes, rather than of different sorts, since the several chemical compounds are not distributed unequally, but are everywhere indiscriminately mingled. No change of composition whatever occurs through a stretch of several degrees of the comet's tail, so far as can be inferred from the spectroscopic evidence.

If the masses of the particles have been changed, it may be asked, will there not be a change in the spectrum? Perhaps not in this case. The change of mass corresponding to the velocity observed in the particles of a comet's tail will be very small, according to the results of Kaufmann's experiment, and need not necessarily produce any sensible change in the spectrum; but at high velocities approaching that of light, such changes would be anticipated, and we have evidence that such changes do occur. It has long been known that vacuum tubes filled with various gases most carefully prepared for exhibition of their several spectra, suffer gradual change, the spectra being eventually reduced to other and simpler ones until at last possibly nothing but hydrogen remains. Attempts to explain this behavior on the supposition of the presence of impurities, or by the occlusion of gases in the walls of the tube, and the gradual absorption or emanation of such residual gases, have been only partially successful. The true explanation which finally emerges is that the atoms of large atomic weight are eventually broken down as a result perhaps of repeated collisions at high speed under electric repulsion, and are resolved into simpler atoms. Sir J. J. Thomson finds that the positive rays in high vacua, where great velocities have been electrically produced, consist of particles of not more than three sorts which are probably hydrogen, the alpha particle, and helium, and that this is so *no matter what gas is put into the tube.* It is notable that the luminous emanation from *Nova Persei* appeared likewise to consist of particles of *three* sorts, and having masses *in the same ratio* (1:2:4) as those observed in the vacuum tube. I think, therefore, there can be no doubt that the nebulosity around *Nova Persei* was an example on an enormous scale of Goldstein's "canal rays."

The recent observations of Comet Morehouse are not clearly decisive for or against the theory of light-pressure. Barnard finds that the motion of luminous knots along the tail is unaccelerated. The development of a comet's tail takes place at the rate of something like 100 km. per second, and is maintained unaltered through distances comparable to that separating the sun from the earth. This result was obtained in a vague way many years ago by Olbers and others, but from observations which rested on the very uncertain limit of the visibility of the extremity of a comet's tail. Barnard's observation is more precise, and is in agreement with the hypothesis of a force whose acceleration diminishes as a result of the motion imparted by its own action.

Next in importance to the observed velocity must be placed any information which can be obtained as to the size of the particles. The

[1] *Astrophysical Journal*, 29, 63, January, 1909.

spectroscopic measures of Comet Morehouse at the Yerkes and Lick Observatories show that the light from the tail proceeds almost entirely from gaseous molecules. But Schwarzschild has shown that there can be very little light-pressure on free gaseous molecules, because their dimensions are so small that they diffract the light and remain themselves comparatively unaffected. If the motion is due to pressure of light, it would seem to follow that the gaseous spectrum of the comet's tail must be that of small separate atmospheres enveloping and attending moving particles which are not otherwise visible, but are the objects directly impelled by the luminous impact. A gradual diminution of size of the particles by electric dissipation or by evaporation would give a diminishing efficacy to the repulsion, but whether this would be compatible with the observed motion can not be determined.

The cometary evidence being indecisive, the argument for the interaction of ether and matter must rest for the present on the observed mechanical pressure of light, and on Kaufmann's experiment, with the addition of such inferences as are suggested by the phenomena of radioactivity and the behavior of matter in highly exhausted vacuum-tubes.

The variety of new properties of matter observed with a high vacuum is sufficiently extraordinary. The interior of a vacuum tube is virtually a new world, where the physical laws with which we are familiar are in appearance frequently contravened. According to the ordinary laws of gases, any gas set free in a vacuum-chamber might be expected to diffuse almost instantly to every part of the exhausted volume. Nevertheless, in heating the gas-regulator of an X-ray tube to restore a minute amount of gas to a tube of too high resistance, the gaseous matter may be seen trickling along the walls of the tube in a network of apparently viscous filaments, the gas behaving as if it were a viscid liquid, adhering to the walls of the tube and reluctant to leave them.

In my paper "An Inquiry into the Cause of the Nebulosity around Nova Persei"[2] I have shown that particles analogous to those of cathode rays were shot off from the star with velocities in some cases scarcely inferior to that of light; and yet, at distances from the center of dispersal which are comparable with those from star to star, the motion bore witness to a control which was not gravitational, but resembled rather a magnetic control emanating from the star. The mere suggestion that a magnetic field can exist at stellar distances capable of guiding particles, of any kind whatsoever, will evoke the exclamation "impossible!" But having learned from the behavior of vacuum-tubes that many very strange phenomena are of every-day occurrence in these novel realms of vacuous space, it may be well to enlarge the bounds of preconceptions.

Professor Speyers's equation (7) does not fit the facts, but his equation (8), which agrees with that given by Professor Lewis, conforms to the data of observation. The source of the discrepancy comes from a failure to distinguish between the mass of the ether and that of the body receiving radiation. If, for clearness, we call the former m' and the latter m,

$$dE = V^2 m' = V^2 dm,$$

and

$$V dm = mv = M$$

(if the velocity of the body receiving the radiation is wholly due to light-pressure, M being the temporary momentum of the ether), whence, since $m = m_0 + dm$,

$$dm/m_0 = v/(V - v).$$

This equation may be substituted for equation (7).[3] It gives for the mass of a particle moving at any velocity up to that of light,

$$m_0 + \frac{dm}{m_0} = m_0 + \frac{v}{V - v} = m_1,$$

or

$$m_1 - m_0 = v/(V - v)$$

and

$$m_1 - m_0 = \infty,$$

if $v = V$, as the theory of Kaufmann's experiment requires.

In saying that "the mass of the body struck

[2] *American Journal of Science*, July, 1903.

[3] *Loc. cit.*

[by radiation] increases as it moves [faster] . . . but only as it receives *this particular form of energy,*"[4] Professor Speyers is, it seems to me, endeavoring to express a distinction which must be recognized, but in terms which can not be admitted if non-Newtonian mechanics is accepted. The mass of the ether is only temporary; it does not become infinite though moving with the velocity of light, and it can be transferred. There are not, however, two kinds of energy—one the energy of mechanical motion, the other, radiant energy. There is only one energy in the physical universe, but two sorts of mass—temporary for ether, permanent for matter, both of them being energy of ethereal rotation. I am entirely in agreement with Professor Lewis that the substance (meaning by this word no ordinary matter everywhere and at all times amenable to gravitation, nor yet a purely metaphysical substance, but a universal interstellar medium which has physical properties different from ordinary matter) "which in a beam of light has mass, momentum and energy, and is traveling with the velocity of light, would have no energy, momentum or mass if it were at rest"; but "if it were moving with a velocity even by the smallest fraction less than that of light," it would cease to be free ether, and would have quite different properties. Now this is just what might be expected if matter is formed from the ether, for however it may be formed, matter must be differentiated from the ether by a *per saltum* change, ordinarily irreversible. Whether we consider the condensation of a large volume of ether containing a powerful luminous energy into the dimensions of a corpuscle still retaining the electro-magnetic energy of the original volume, or regard the birth of an elementary particle as in the nature of a cataclysm which opens a rift in a medium of great strength and density, in other words, whether we conceive the ultimate particles of matter to be vacuities in an exceedingly dense ether, kept from collapsing by the centrifugal pressure of a rapidly rotating shell, or as condensations in an elsewhere excessively rarefied medium, in either case the circumscribing of a definite volume with properties other than those of the general medium presupposes a surface of discontinuity of some sort around the segregated portion, such as might be produced by a sudden change in the ethereal velocity at this singular surface. It may be a question whether the permanent mass (m_0) of a material body is exactly equal to its ethereal angular momentum divided by the velocity of light

$$m_0 = M'/V.$$

The circumscribing of the ethereal motion may be attended by some departure from the universal velocity in the free ether, but this is simply to say that the materialized ether is distinct from the free ether.

In an article in *Nature*[5] Professor Larmor, in commenting on the fact that the Doppler effect requires "some kind of thermodynamic compensation, which might arise from ethereal friction, or from work required to produce the motion of the body against pressure excited by the surrounding radiation," says: "The hypothesis of friction is now out of court in ultimate molecular physics," but it comes into court again with the discovery that atoms are destroyed and that new radiant energy is thereby imparted to the ether. If radiation, in turn, generates mass, as I have suggested in my paper, "A Cosmic Cycle,"[6] or in the less problematical way which Professor Lewis has now virtually demonstrated, it is difficult to conceive how this can be done without some sort of ethereal reluctance analogous to viscosity in a gas; and granting such a reluctance, we might anticipate some retardation of the normal ethereal velocity in the transformation.

In the paper cited, I have defined energy as "the modification of ethereal rotation, or the establishment of rotation at new points in the ether." Radiant energy is electromagnetic rotation of the ether, differing in no wise essentially from the ethereal rotations within an atom whose energy makes the atomic mass,

[4] *Loc. cit.*, p. 657.

[5] Vol. 63, p. 216, December 27, 1900.

[6] *American Journal of Science*, 13, 193, March, 1902.

save that the latter is very nearly permanent. Not a special velocity *per se*, but the being, or ceasing to be, of a special ethereal rotation is what apparently conditions the phenomenon.

As Mons. Hirn says in his attempt to define energy:[7]

> What we call kinetic energy or mechanical work consists of quantities which are not necessarily bound to the existence of ponderable matter.

To borrow an illustration from Hirn, we may compare the following two ways of heating a bullet. When a projectile, such as a ball of lead, strikes a rigid obstacle, it becomes hot, and the quantity of heat developed (and divided between projectile and obstacle) is rigorously proportional to the external kinetic energy which has vanished for the time being. But we can heat the leaden ball just as well by exposing it to the sun's rays; and here again the temperature, or elevation of thermal activity, is related to the radiant movement extinguished. The kinetic energy of the radiation, which was that of an original radiant beam or column of ether, has been destroyed as radiant energy, but not as essential energy. The energy has simply been transferred; but there is a distinction between the two modes of heating the bullet. The radiant energy extinguished is *completely* transferred to the absorbent. The thermal energy developed by impact is divided between missile and obstacle. This distinction is fundamental, and prevents the identical application of a law expressing the relation between ethereal and material energy, to the interchange of energy between different portions of matter. Kaufmann's experiment belongs to the first category. The distinction, which has no counterpart in the transference of momentum by sound waves or water waves, has its place in the system proposed by Professor Lewis. The kinetic energy of a mass which moves with the velocity of light is mV^2, but that of a mass moving with the ordinary velocities with which we have to deal in Newtonian mechanics is $\frac{1}{2}mv^2$. That the distinction is not an absolute one, but that for velocities somewhat slower than that of light, the mathematical expression for kinetic energy passes through intermediate values, is a view which reconciles these diverse modes of subdivision of energy.

I venture to suggest that Mr. Speyers's difficulty in regard to the lesser velocity of light in water is not a real one; because owing to innumerable, minute, alternating deflections of the light ray in passing through the bound ether attached to the molecules, the path of the light is lengthened. There is no necessary change in the true ethereal velocity.

Ordinarily, the mass of a body of matter can not be transferred; but in radioactivity, and in atomic disintegration and destruction produced in any way, energy returns into the ether, and may be transferred as temporary ethereal mass, just as in the case of radiant energy, of which it is perhaps a special form. The ordinary destruction of atoms is excessively slow, nevertheless every flame involves *some* minute amount of atomic destruction.

The laws of the conservation of mass and of energy require restatement. Taking the universe as a whole, there is always a restoration of mass or of energy which disappears in time at some given point, but in general reappears at some other time or place. Thus if atoms are destroyed in radioactive transformations, there must be some other part of the universe where these atoms are reproduced. Temporarily the energy concerned in the formation of an atom is set free in the destruction of the atoms of radium, evolving enormous quantities of heat. Some of this heat may be immediately transformed and all will be eventually transformed into radiant energy, passing out into the free ether, there to exist for a time as temporary mass until it is again fixed in new forms of *material* substance, for the ether is the great storehouse of energy. Shall an atom outlast a star? Are they not both parts of a fleeting imagery—a series of dissolving views which come and go as the ages move?

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Westwood Astrophysical Observatory,
May 3, 1909

[7] "La notion de force dans la science moderne," p. 47.